INSTRUCTIONS

FOR

OBSERVING THE TRANSIT OF VENUS,

DECEMBER 8-9, 1874,

PREPARED BY

THE COMMISSION AUTHORIZED BY CONGRESS AND PRINTED FOR THE
USE OF THE OBSERVING PARTIES BY AUTHORITY OF
THE HON. SECRETARY OF THE NAVY.

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1874

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[GENERAL ORDER.]

NAVY DEPARTMENT, *May* 29, 1874.

The parties organized by the Secretary of the Navy to observe the transit of Venus in December, 1874, under the authority of an act of Congress approved March 3, 1873, are organizations invested with naval character, and subject to naval rules, regulation, and discipline. The command of each party is assigned to the chief astronomer, to whose authority all others will be obedient.

The following is the order of rank and authority in each party, viz:

1. Chief astronomer.
2. Assistant astronomer.
3. Any other assistant astronomer attached to the party.
4. Chief photographer.
5. First assistant photographer.
6. Second assistant photographer.

This order will be respected and followed as the order of rank and succession in each party under all circumstances, including the contingencies growing out of any separation of the party, or the happening of any vacancy.

The parties destined for the southern hemisphere, about to embark in the United States steamer Swatara, will be personally subject to the authority of the commanding officer while on board that ship, and to its discipline, police authorities, and regulations.

The gentlemen engaged in this interesting and important service will easily and fully understand that discipline, harmony, and co-operation are essential to its satisfactory performance as well as to their own safety and convenience, and that for this reason they have been required to assume the obligations, and are subjected to the rules of the naval service.

GEO. M. ROBESON,
Secretary of the Navy.

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NAVY DEPARTMENT,
Washington, May 20, 1874.

The following instructions, prepared by the Commission on the Transit of Venus, are issued, under the authority of this Department, for the guidance and government of the parties charged with the duty of making the observations of the transit. Every person engaged in the scientific operations is enjoined to study them carefully and to conform to them strictly.

GEO. M. ROBESON,
Secretary of the Navy.

INSTRUCTIONS

FOR

OBSERVING THE TRANSIT OF VENUS.

DECEMBER 8-9, 1874.

General instructions.

The chief of the party will see that the instructions are complied with in every particular, and he will be held responsible for their proper execution.

Of the journals and memorandum-books, each observing-room is to have at least one for its exclusive use, in which all the operations shall be recorded in detail, with all the particulars necessary to their being fully understood. A journal is also to be kept in which all the operations of the party must be recorded.

All observations should be recorded, in the first place, in the proper forms, in the note-books. If, from any cause whatever, it should be found necessary to make the rough notes of an observation on loose slips of paper, these slips must be carefully kept, and pasted in the regular book in the proper place, where they must also be copied in the usual forms. A number, when once recorded, should never be erased. If the observer sees that it is wrong, he must make a mark through it, and write the correct number alongside of it. If he concludes, from subsequent observations, that a number is probably wrong, he must note that fact at the foot of the page, but make no change in the record.

In this first record, numbers should not be added or filled in which are the result of subsequent calculation. For instance, if the observer fails to note the minutes of the chronometer corresponding to any observation, he must not conclude what they were from the preceding or subsequent observations, and then put them in, but must omit them entirely. If, however, this omission would cause subsequent uncertainty, the necessary numbers may be put in, but must be underscored.

As soon as possible after each series of observations are made, they are to be copied with ink, each class in chronological order, into another book. In the case of observations for which blank forms are provided, the copy may be made in other forms of the same kind. All the others must be copied in a single large book. In this copy the preceding regulations respecting additions and alterations is not intended to apply, but the observer will always make what he believes to be a full and correct record, underscoring numbers which are added or altered from the original record.

The chronograph sheets must be read off and recorded in the proper books.

In observing with the chronograph, the minutes and seconds must always be marked at least twice during each series of observations, and all the chronograph sheets must be preserved and returned with the other original records.

All records of observations must include every particular necessary to their being completely understood. For instance, wherever clock or chronometer time is given, the particular clock or chronometer is to be designated; where level readings are given, the direction of each end of the level, east, west, north, or south, must be recorded; when the images of lines on the plate-holder are observed with the transit, the direction of the image from the middle wire, whether right, left, north, or south, must be stated, as well as the direction of the eye-piece of the instrument, east or west; and all photographs of the sun must indicate the exact time at which they were taken, and must be so marked that the position of the plate when in the holder—that is, the top, bottom, east, and west sides—can always be distinguished.

The chief of each party will transmit all the records to the president of the commission as soon as practicable after the completion of the observations. They will be sent in separate packets, one containing the journal and all the original pencil memoranda of the observations, the other the fair copy already directed to be made. If practicable, the two packets must be sent at different times and by different conveyances. From ports where an American consul is stationed, they may be forwarded by him through the Department of State, in which case he must be notified to send the two packets by different ships.

No observations or results will be published by any member of the parties without authority of the commission. This prohibition is not intended to prevent any general statements respecting the nature and success of the work which the observers may choose to make. In cases of co-operation with any other individual or party, the chief of the party is authorized to communicate to the other copies of all observations necessary to the special end for which the co-operation was entered into.

Selection of point of observation.

The following are the points to be principally attended to:

A good foundation for the instruments. A sandy soil is not bad, if damp.

A nearly level line, sixty feet from north to south, should be chosen for setting the transit-instrument and photographic telescope. A rise or fall of one foot from the transit-instrument toward the photographic house—that is, toward the south in the northern hemisphere and toward the north in the southern hemisphere—will not be inconvenient; but if the change of level exceeds this amount it will cause inconvenience, which will have to be partially remedied by digging away the ground at the end which is too high, and raising the building which is at the low end.

Shelter from the prevailing winds is to be sought for; but great care must be taken that the sun be visible from the point occupied by the photographic objective and by the equatorial telescope during the whole time of the transit, and, indeed, a little longer. For this and other purposes, the observers must make sure of the exact local time of all the contacts.

Laying off ground and setting piers.

The approximate position of the meridian-line, on which are to be placed the three piers supporting the transit, the photographic objective, and the plate-holder, being determined by compass or otherwise, the next two operations, which may be carried on together, will be the laying down of an exact meridian-line and the erection of the pier for the transit.

The latter should rest on a base three or four feet below the surface of the ground, and, in the northern stations, below the reach of frost, if practicable. The last earth at the bottom of the excavation should be carefully removed with a spade in horizontal slices, so as neither to disturb the bottom on which the pier is to rest nor leave loose earth underneath the pier. It will be desirable to leave a narrow vacant air-space around the pier to a depth of two or three feet below the surface so that the earth shall not press against the sides of the pier. The earth must then be kept from the pier by a wall of brick, stone, or wood. Above the ground, the pier should be two or three inches smaller than the stone cap; below, it may be as much larger as circumstances will permit.

While the transit-pier is building, and, indeed, as soon as its position is decided upon, a point should be selected about seven feet east or west of its center, from which to lay off a meridian-line by the theodolite. The latter instrument being placed over this point, instead of trying to stake off a meridian-line at once, it is best to begin by driving a stake or making a mark as nearly south or north of the theodolite as practicable, and then to find the azimuth of the line joining the instrument and the stake by observations of sun or stars on both sides of the meridian. Then the positions of the holes for the iron piers of the photographic instruments will be found by laying off offsets from this line at the proper points and to such distances as to bring the piers all in the true meridian. The distance of centers of holes should be 15 inches greater than the focal length of the objective. But the piers must not be finally set in the holes until the transit-instrument is brought into the meridian, and the collimation and azimuth errors made as small as practicable.

When this is done, the objective of the transit must be covered with a cap, having a slit about one-fifth of an inch in diameter cut across it; and this cap must be turned so that the slit shall be truly vertical. It will then be possible to obtain tolerably distinct vision of any vertical line more than one-fifth of an inch in diameter in the meridian of the instrument. Then, by finding where a vertical rod is in the meridian of the instrument, the position of the centers of the holes for the two iron piers will be more exactly determined. A yet more convenient method may be to mount the theodolite behind the transit-house in the meridian of the transit, but a little higher, so as to see the piers over it. Then point the transit and theodolite on each other so that the images of their central wires shall coincide, when the theodolite will be in the meridian of the transit. The central points of each pier can then be brought into the meridian of the theodolite by looking through the slits of the transit-house with the latter instrument.

The exact depths of the holes are to be determined by an engineer's level. The bottom of the excavation for the objective pier must be 8′ 6¼″ lower than the center of the eye-piece of the transit-instrument, and that for the plate-holder 8′ 7″ lower. To determine these depths, mark these distances off on a rod; set a level in such a position that the eye-piece of the transit and the points where the objective and plate-holder are to stand can be successively brought into the field of view of the level; and then see that, when the rod is placed erect in the bottom of either excavation, the proper mark is at the height of the eye-piece of the transit-instrument.

It will be better to dig the holes a few inches deeper than is necessary, and to fill up the bottom with concrete until it is exactly at the right depth, if the party has cement to spare for the purpose.

The iron pipes, of which the larger, with flanges on each end, goes next the transit-instrument, are then to be placed in the holes, and temporarily secured; but, before being finally set with cement, it must be ascertained that their positions are in every respect correct. To insure correctness, insert in the top of each tube a disk having a hole through its center, and in this hole set a pin from $\frac{1}{4}''$ to $\frac{1}{2}''$ diameter, and 6″ to 12″ long. Then,

1. These two pins must be in the true meridian as seen through the theodolite or the transit-instrument with the slit cap. To insure against error, turn the cap 180°, and see if the pins appear in the same position; if they do not, the mean of the two positions, which can be judged by the eye, is the correct one.

2. The distance between the pins as measured with the steel tape-line must be exactly 15 inches greater than the focal length of the objective, which is marked on the cell.

3. The heights of the tops of the piers as determined with the level must be correct, the objective pier being $6\frac{1}{4}$ inches and the plate-holder pier 7 inches below the level of the eye-piece of the transit.

4. In order to avoid troublesome adjustments, the piers must stand nearly erect by the small levels.

5. Of the screw-holes on the objective pier, one must be on the side next the transit and the other two east and west, while of those on the plate-holder pier two must stand in a north and south line, while the remaining one is either due east or west of the center.

When they are all right, fill in around the outsides of the piers with mortar or concrete to nearly the level of the ground. But this final setting had better be delayed, at least in the case of the objective pier, until the apparatus has all been placed in position and the photographic focus tested. The inside of the pier is to be filled in like manner to the height of four or five feet.

The photographic house is to be built around the farther pier, and the floor is to be of such a height above the ground that the hole for the photographic tube comes into its proper position relatively to the top of the plate-holder.

The cast-iron plates which support the objective and plate-holder are now to be fixed in place on top of their respective tubes. The coffin-shaped plate which supports the objective and the heliostat is to be screwed down to its pier, with the long end turned away from the transit-house and the pipes which take in the holder of the objective downward. The forked piece which carries the objective is to be set into these holes, in which it may at first be wedged with pieces of metal, but afterward, when found all right, should be screwed down and set with plaster or cement.

The round disk which carries the plate-holder is to be screwed on the tube in the dark room by the binding and supporting screws, taking care that it is turned in the right direction. If the brass cross which carries the plate-holder is not already screwed to the disk, it must be well screwed down, its tube going down through the disk.

The frame or photographic plate-holder is next to be set in place by setting its vertical axis in the tube of the cross. See that, when turned on its axis, its two ends shall just graze the raised ends of the cross below it. When brought round into the right position facing the objective, it is to be fastened by means of the screws which pass through the slots at the end.

Adjustments of the photographic instruments.

The exact adjustments of the photographic plate-holder and objective are to be attended to. They are as follows:

1. The distance between the photographic sensitive plate and the objective should be equal to the focal distance of the latter within a fraction of an inch.
2. The line joining the optical center of the object-glass and the cross-lines in the middle of the photographic plate-glass should be in the true meridian within a fraction of a minute of arc.
3. The same line should be horizontal within the same limits.
4. The optical axis of the objective should be directed toward the center of the photographic plate.
5. The plate should be perpendicular to the line joining its center and the center of the objective.
6. The bubble on the long level of the plate-holder should be at rest nearly in the middle, or, at least, should not touch either end of the tube.

These adjustments are made as follows:

1. Measure with the tape-line the distance between the inner face of the object-glass and the center of the plate-holder. The distance should be that marked on the cell.

Note how much too long or too short the distance is. If the error is not over one-half inch, it may be regarded as unimportant; if it is over, it should be corrected.

To guard against error, after the adjustment 4 is made, the plate-holder should be removed, and a number of photographs of the sun taken at different distances inside and outside the focus. The points at which the small spots on the sun begin to disappear when the plate is too far in, and again when it is too far out, must be noted. The mean of the two positions is the true focus. If, after repeated trials, this point is found to differ an inch or more from the point found by measurement, the position of the objective must be changed accordingly.

2. When the objective is screwed into place, the observer can, by turning the transit horizontally toward it, see the ruled plate, by the light of a lamp, in the proper position. To make sure of seeing and identifying the proper lines, draw a little cross, with ink, on the ruled plate, exactly over the point of intersection of the central lines.

The lines of the cross need not be more than half an inch long, and they should coincide exactly with the ruled lines. In the day-time the lines can be best seen by reflecting the sun's rays upon the ruled glass. The vertical line in the middle of the plate should then, if the azimuth and collimation of the transit are quite correct, be on the vertical wire of the transit. Probably it will be found at some distance from the vertical wire. In this case its error of position must be estimated as carefully and accurately as possible, making due allowance for the errors of collimation and azimuth. The amount by which the plate-holder must be moved east or west to bring it into the true meridian must then be computed. The base of the plate-holder must then be adjusted in the slots which fasten it to the iron disk below, until the central line is exactly in the meridian of the transit.

3. Point the transit so that its middle horizontal wire shall accurately cover the image of the middle horizontal line on the plate-holder, and clamp it firmly in that position. Then set up the level between the transit-house and the objective, and point it into the photographic telescope so as to see the ruled plate. Bring the image of the same line on the plate into exact coincidence with the horizontal wire of the level. To make the coincidence exact, the observer should go inside of the photographic dark room, and look through the plate-holder with a lens or eye-piece of one or two inches focus, while an assistant holds a lamp in front of the eye-piece of the level. The observer must then call to the assistant in which direction to move the level so as to see the image of its horizontal wire exactly coincident with the coarse line of the plate. If the bubble of the level, supposed to be accurately adjusted, is then within six or eight divisions of the middle of the level, the adjustment is probably near enough. To make this sure, however, point the level at the transit-instrument, and bring its horizontal wire into exact coincidence with that of the transit in the way just described in the case of the photographic telescope, and again read the level. Half the distance traveled by the bubble in the level-tube between the two readings will show the error of level of the photographic plate-holder.

The probability is that on the first trial the bubble will run all the way to one end or the other of the tube. If it runs to the end next the photographic house in each pointing, this will show that the plate-holder is too high, and the disk which supports it must be let down by the adjusting-screws until the bubble of the level is near the middle when the coincidence of wires is properly made. Then, if, on pointing the transit on the photographic telescope, as before, and then pointing the level on the transit, the bubble is not more than ten or twelve divisions from where it is when pointed on the photographic telescope, the adjustment is near enough.

4. The photographic plate-holder being thus fixed in position, the observer must adjust the objective, by its three supporting-screws, in such a way that, standing in the dark room, and holding a candle or reflector in a line with the center of the ruled plate, the three reflections of the candle from the object-glass shall all coincide with the candle itself, or the hole in the reflector shall, in the same position, coincide with its three images. A round disk of card-board, two inches in diameter, with a hole one-fourth of an inch in diameter through its center, makes the best reflector for night use.

5. Standing in the farther side of the photographic room, and looking through the center of the plate-holder down the telescope-tube, see that, when the candle or hole coincides with its image reflected from the glass of the plate-holder, the line of the reflection passes directly down the center of the tube. If it does not, the necessary adjustments must be made, in altitude by the screws of the iron disk which carries the plate-holder, and in azimuth by turning the frame round its vertical axis. When right, the proper screws must be passed through the slots in the small uprights at each end of the base of the frame, and tightened.

This adjustment may be made more exact by mounting a theodolite or level in the line of the objective, and seeing its reflected image through it.

6. Move the side-screw of the disk until the bubble on the plate-holder remains nearly at rest as the frame is turned on its vertical axis. It is more especially necessary that when the plate-holder is at right angles to the line passing through the photographic objective, the bubble should rest near the middle of the tube both in the direct and reverse positions of the plate-holder. This may require one end of the level to be loosened and screwed down again, with a sheet of tinfoil under it.

Determination of instrumental errors.

The adjustments 1, 4, and 5 being once made, it is expected that they will remain exact, unless something is disturbed; if, however, 4 and 5 are disturbed, or found wrong, they must be corrected. But 1, 2, 3, and 6, provided that they remain very small, instead of being corrected, are to have their errors *determined* at least twice a week.

To find the changes of No. 1, the distance between the face of the ruled plate and the face of the objective are to be measured with the greatest care and exactness by the measuring rod at times when the temperature is not varying rapidly and the sun is not shining on the rod, according to the directions hereafter given.

Every evening, before beginning observations with the transit, turn the eye-piece of the latter on the side where the opposing azimuthal adjusting-screws are, and adjust the azimuth so that the middle vertical wire of the transit shall be nearly or exactly coincident with the image of the middle vertical line of the plate-holder. If there is any outstanding deviation, measure it with the micrometer. The azimuthal adjustment of the transit must then remain undisturbed during the night's work. Then reverse the instrument, and measure the deviation of the vertical wire of the plate-holder. The deviation of this measure from the first will be double the error of collimation, which may be corrected when greater than seven seconds of arc, or half a second of time. At the close of the night's work the same deviations must be again measured, but the position of the instrument must not be altered.

The azimuth error of the transit must be computed from two pairs of stars for every night's work, and if it be found to exceed one second of time during several nights, the plate-holder must be adjusted by moving its base in its slots one-thirtieth of an inch for each second of error.

The measures described for testing adjustment 3 should be repeated, and all the readings of the level and transit micrometer recorded.

The heliostat.

When the preceding adjustments are all made, the heliostat is to be set in its place on the coffin-shaped plate in front of the objective. As it will have to be removed from time to time to determine the instrumental errors, it will be necessary to mark where its feet stand, and, if practicable, to make small conical holes in the iron to receive them.

To set the heliostat in the plane of the meridian, it is necessary, first, to set the mirror at right angles to the main axis of the heliostat, and then to set the latter so that the reflecting-surface of the mirror shall be at right angles to the photographic telescope. The first adjustment is made when, the main axis of the instrument being turned round and round, there is no change in the apparent direction of an object seen by reflection from the first face of the mirror. Always take care that the reflection from the first face, and not that from the second, is used. Then, setting the heliostat so that, when the light of a candle is reflected down the center of the telescope-tube, it will be reflected back to the same point, the main axis is horizontal and in the meridian.

The main axis must be set at the proper angle, as given hereafter, by the best available method. This may be done by the theodolite.

The plumb-line of the plate-holder.

Both the chief of party and chief photographer must give especial attention to the plumb-line of the plate-holder. It must be entirely free from bends and kinks, and be loaded with as great a weight as the wire will safely bear. The weight must be hung in a vessel of water in the pier, great care being taken that it hangs freely, with room to swing. If possible, it must not be removed or disturbed during the month preceding the transit.

The tube and measuring-rod.

After the above adjustments are all made the tin tube of the photographic telescope must be put into place. In doing this, the main points to be attended to are, (1,) to have the centers of all the openings in the diaphragms in the straight line passing from the center of the objective to the center of the plate; (2,) to have the supports for the measuring-rods in a right line, so that these rods, when in place, shall be in a straight line from end to end.

These supports must be provided by the party as soon as possible after the instruments are adjusted. They may be formed either by soldering Y's on top of the tin tube, or by building a frame-work over the latter and cutting notches in it to receive the rods. The rods must be screwed together so that the shoulders shall meet snugly. Marks at each joint show the exact point of stopping. One end of the combined rod must pass through a small hole in the photographic house; the inner end should be about as far from the vertical of the plate-holder as the outer end is from the vertical of the object-glass, and the whole rod should lie as nearly as possible in a straight horizontal line. When once fixed, it should remain in position.

The tube and rod must be protected from the rays of the sun by a roof or canvas awning, with an air-space of from six to twelve inches around the outside of the tube. This is imperative, and if, from any cause whatever, it is impracticable to protect the entire length of the tube, the unprotected portion must be entirely removed, as a tube heated by the sun's rays is far worse than none at all.

The equatorial.

The mounting of the equatorial must be commenced as soon as possible, taking precedence of that of the photographic piers. The instrument must command a good view of the eastern and the western sky to within five degrees of the horizon, if practicable.

Observation of occultations.

All the visible occultations of stars by the moon which occur during the stay of the party are to be carefully observed. To facilitate these observations, the times of the emersions which occur after the full moon are to be computed beforehand.

From the time the new moon first becomes visible until her full, she is to be carefully watched with the telescope to see what stars she is going to occult. These can be seen half an hour or an hour beforehand by remembering that the course of the moon in the heavens is nearly at right angles with the line joining her cusps, and that she moves nearly her own diameter in an hour. Whenever there is a chance of seeing an occultation, a map of the relative positions of the moon and the stars in the neighborhood must be made; and if the occultation is actually observed, the exact point of the moon's limb at which it disappeared must be noted on a little sketch. Nothing must be recorded as an immersion or emersion except the actual sudden and distinct disappearance or re-appearance of the star at the moon's limb. If the star is lost in the moon's rays at this moment, the fact should be stated. Every observation must also state, under the head of "Remarks," whether the occultation was well observed, and, if not, what the greatest amount of uncertainty is.

Great care must be taken to guard against errors of 10^s in the record of the occultations, and, to this end, it will be well to have an assistant call aloud every tenth second, "0," "10," "20," etc.

The chronometer or clock by which every occultation is observed must be mentioned.

The occultations may be also observed on the chronograph. In this case it will always require a fraction of a second for the observer to become conscious of the phenomenon, and to give the signal, and this interval must always be estimated by the observer and recorded in the memorandum-book. But, the chronograph must never be trusted to exclusively, and, when used, either the observer himself or his assistant must note the chronometer time of the occultation, or of the signal with the key.

Determinations of time.

Four azimuth stars and six or eight time stars must be observed every night with the transit when practicable. One-half the observations of each class should be made in each position of the instrument.

Clocks and chronometers.

Whatever chronometers are left at the station must be compared every morning and evening. It is not necessary to compare each one with all the others, but the particular chronometer that is carried around must be compared with each of the others and with the clock. All the others must, as far as possible, be kept unmoved; and the temperature of the place where they are located, and also of the air inside the clock, must be recorded four times a day at intervals as nearly equal as possible. The clock must be protected from changes of temperature as well as circumstances will permit by surrounding it with some non-conducting material.

Should any opportunity offer for the comparison of chronometers with those of parties from other countries, it must be improved. Visits from such parties may be expected at Kerguelen, Bluff Harbor, and possibly Crozet's Island.

Operations on December 8 and 9.

On the day and evening preceding the transit, and again on the evening of the transit, or the day after, the following instrumental determinations must be made with great care:

The errors of the clock and chronometers by observations with the transit. Owing to the uncertainty of weather, no night must be allowed to pass, during the week preceding December 8, without observing the transits of several stars for clock-error should weather permit; and if the night observations are interfered with by clouds or any other cause the transit of both limbs of the sun must be observed every day during the same period, the transit being reversed between the limbs.

Measure the distance between the plate-holder and objective. Repeat this measure on the morning or afternoon of the transit, according as the time at which it occurs gives the better opportunity.

Determine the error of level of the photographic telescope.

See that the equatorial and double-image micrometer are all in good working order.

Take reversed photographs of the lines of the plate-holder.

See that adjustments 4, 5, and 6 are all correct.

That the axis and mirror of the heliostat are at the proper angles.

And, in general, that every part of the apparatus for observing and photographing is in perfect working order.

On the day of the transit, (December 9, when the day is reckoned east from Greenwich,) the equatorial must be pointed at the sun, the clock-work set running, and the highest-power eye-piece, with the ruled scale, be put into the tube early in the morning. If no ruled scale is furnished the double-image micrometer must be used, the reading of the micrometer for coincidence of images having been previously accurately determined, and the micrometer set at this reading. The observer with the equatorial must not allow his attention to be distracted by anything else during the half-hour preceding first contact. In order not to fatigue his eye, he must not commence regularly looking for the first contact until about a minute and a half before the computed time. To guide him, both the chronometer-time of contact, to the nearest tenth of a minute, and the point of the sun's limb where the first contact is to occur, must be carefully computed. He should have an assistant, any one the chief of the party may select, to call the tens of seconds, as in occultations, to beat the single seconds with a key if necessary, and to record the times and readings if the observer shall require it.

As the observer must know very nearly where to look for the first contact, he must make use of the position-circle of the double-image micrometer. Turn the eye-piece on the circle until the limb of the sun, or, better still, some spot on the sun, runs along the wire, or any other line by its diurnal motion, when the telescope is not moved, or when, the clock-work going, the telescope is moved in R. A. by the slow motion. Note the reading of the index on the circle. Then turn the eye-piece by the milled head, the upper part toward the observer's left, the direction being the opposite of that of the hands of a watch, through the angle Q_1. This angle ranges from 47° for the southern stations to 51° for the northern stations. (See memoranda). The line along which the sun ran will then be parallel to the limb of the sun at the point where contact is to occur. Set the telescope so that this line shall cut off a small segment of the sun. The middle of this segment will be the point of contact. To avoid the possibility of error, the required position of the index must be repeatedly determined with great care.

To guard against serious error it must be remembered that at the northern stations contact occurs between 70° and 80° east from the highest point of the sun's limb. At Kergulen and Crozet it is almost at the lower point of the limb. At Hobart Town it is between 35° and 40° east of the lowest point of the limb; at Bluff Harbor about 70°, and at Chatham Island nearly 90° in the same direction. The terms upper, lower, east, and west, here apply to the image as seen with an erecting eye-piece, like that of the double-image micrometer. If an ordinary eye-piece is used they must all be reversed.

The first time to be recorded will be that when the indentation of Venus on the sun's limb is first certainly seen. If, from any cause whatever, the observer fails to recognize it when it first becomes visible; or if, in any way, the aspect of the notch when first seen is materially different from that made by the artificial Venus on which the observers have practiced in Washington, these facts must be clearly stated.

As the indentation widens, the chronometer-times at which it attains different lengths, as measured on the ruled plate, must be recorded.

When the indentation becomes so wide that these times are entirely uncertain, which will be in less than ten minutes after first contact, the double-image micrometer must be attached to the telescope, and adjusted so that the line of separation of the images shall coincide with the edge of the sun at the point where Venus is. The distance apart of the cusps cut off from the limb of the sun by Venus must then be measured as fast as the observer can get good and satisfactory measures; the chronometer-time of each measure being recorded. In taking measures with the double-image micrometer, the measures must always be taken on alternate sides of the zero. At first the cusps will be very blunt; but about ten minutes before internal contact they will have begun to sharpen, so as to admit of very accurate measurement. *In taking these measures, a light-colored shade-glass must be used, so that the image of the limb of the sun shall be as bright as the eye can bear without inconvenience or loss of distinctness.*

As passing clouds, haze, or want of the right glass may interfere with the exact execution of this rule, the observer must indicate the degree of brilliancy of the cusps to the recorder with every measure, as,

Very bright, to be indicated by V. B.
Bright, " " B.
Average, " " A.
Faint, " " F.
Very faint, " " V. F.

He must also indicate whether the cusps appear sharp or blunt. In the latter case, the blunt ends must not be made actually to touch each other in the measures, but the relative positions must be midway between that of actual touching and that in which the cusps would just meet if continued, so as to terminate in sharp points.

One minute and a half before the computed moment of internal contact, or sooner if the external contact was seen before the computed time, these measures must cease. The micrometer must be set at the reading for coincidences of images, which is to be carefully determined beforehand, and the observer must begin looking for the moment of internal contact. He must be careful not to know the exact time when contact is expected, as his judgment may thus be influenced. Between the sharp cusps of the sun, which, it may be expected, will be somewhat indistinct at the points, and will be in a state of tremulous vibration, a dark space will be seen joining the planet to the background of the sky. The true moment of contact would be that at which the sharp cusps meet through this dark space. But, owing to atmospheric vibrations and want of power in the eye and the telescope, the cusps will not meet each other sharply. The observer must take as the true moment of contact that at which light is first seen to glimmer all the way across the dark space referred to. As there may be several appearances and disappearances of this glimmering thread of light, the observer must judge of a mean time at which the periods of appearance and disappearance were of equal length, and record this as the moment of internal contact. The optical appearances about the time of contact must be fully described.

The observer will then turn the double-image micrometer at right angles to its first position, and take a number of measures of the thinnest portion of the strip of light between Venus and the sun's edge. These measures may be continued from five to fifteen minutes or longer; the time depending on whether the observer is required elsewhere for the management of the photographic operations, which are now of the first importance.

After this time no further use need be made of the telescope, until half an hour before the third contact, when the observer must return to it, and prepare for the observations of egress. He must allow himself several minutes, as many as can be spared from the dark room, to take micrometric measures of the thickness of the strip of light between Venus and the nearest limb of the sun. When this is done, and one or two minutes before the time of internal contact, he must prepare for the observation of the latter. The same directions respecting the darkness of the shade-glasses are to be observed as in the case of the ingress. As the thread of light grows thinner and thinner, it will become darker, and assume an ill-defined hazy appearance, the dark body of the planet seeming to be joined to the sky by a waving mixture of light and darkness. So long as lines of sun-light are seen to wave all the way across this space, internal contact has not taken place. The moment at which they cease so to extend, and a narrow strip of the waving light seems to congeal, is to be recorded as that of true internal contact.

As soon as the contact has been recorded and the minutes and seconds of the chronometer verified, the observer must turn the double-image micrometer until its line of motion is parallel to the line joining the sharp cusps, and take as many measures as possible of the distance of the latter in the same way as directed for ingress. As the planet passes off the sun, the double-image micrometer must be removed, and the highest-power simple eye-piece substituted, if it is furnished with a scale. The length of the chord joining the cusps must be noted on the glass scale as often as possible in the same way as in ingress. Finally, the moment at which the planet is last seen is to be recorded.

The photographic operations.

After the photographic instruments are in place, the whole party must, from time to time, be drilled in the photographic operations. In the expenditure of material, care must be taken to leave plenty for two hundred pictures on the date of the transit. In this drill, the operations must be conducted as hereafter directed in the case of the transit, all necessary particulars must be recorded in the regular book, and the plates must be properly marked; but enough of the preliminary pictures themselves must be removed from the glass plates to leave two hundred plates for use on December 8–9.

On the morning of the transit, the break-circuit chronometer must be brought into the dark room; the time by that chronometer at which the first and fourth contacts occur must be carefully computed; and the chronograph-key must be brought to the dark room and connected with the chronograph on which the clock or break-circuit chronometer must be recording its beats. The exact position at which external contact occurs must be determined from the angles hereafter given, and the sun's rays must be cut off by a shade between the slide and the plate, so as to admit only a small portion of the disk in the neighborhood of the point of contact. A strip of the sun's edge one inch long by half an inch into the interior of its disk will be ample.

Immediately before the computed time of contact, the slide will be drawn back, and a sensitive plate will be placed, not in the plate-holder, but in some movable support immediately in front of it, and in such a position that, when exposure is made, the uncovered part of the sun's image shall fall near one vertical edge of the plate. An exposure will then be made as nearly as practicable at the computed moment of first contact; the plate will then be moved one inch, and a second exposure will be made, and so on to as many exposures as the plate will admit of. The chronometer-time of each exposure must be noted and recorded, and the time must also be marked on the chronograph. To effect this, the key must be so arranged that the observer shall press it and release the slide at the same moment; and if the apparatus can be fixed so as to close the key automatically by the slide, it will be yet better. Each exposure on any one plate must be lettered in regular order, *a*, *b*, *c*, etc., and these letters must be marked in the journal opposite the corresponding chronometer times.

The object of this arrangement is to have as many photographs as possible of the indentation made by Venus on the sun's limb during the first five or ten minutes of the transit. Therefore, while one plate is being exposed in the manner described, another must be preparing, so as to continue the process with the least possible delay. The exposures must be made as rapidly as the operations can be conducted and the times recorded with the proper care.

The regular photographs of the transit must then be commenced. In the division of the labor of this important operation, it should be the exclusive business of one person to see that everything is working properly, especially that the chronograph and heliostat are running, and that the latter goes at the right rate, and is not allowed to run down. The remainder of the force must be devoted to the taking of the pictures, and the record of the following particulars in proper ruled forms:

1. A number, to be distinctly marked on each negative.
2. The chronometer-time of exposure.
3. The reading of the level on the plate-holder.
4. The direction (east or west) of the small arm on top of the frame, from the center of which the plumb-line is passed through the plate-holder.
5. The temperature in the room at the time of exposure.
6. The direction of motion of the slide, (east or west.)

In taking the pictures, the slide must be moved alternately east and west, and the direction of the arm carrying the plumb-line must also be frequently changed.

In developing the picture, the sharpest and best-defined edge must be sought for, without regard to the details of the solar surface; and the image must be as dark as possible to the very edge. To attain this end, the central portions must be a little overexposed. If the image is found to shade off toward the edge in any considerable degree, the time of exposure must be increased, first by widening the slit, then, when this is fully open, by lessening the tension of the spring. If the exposure is still insufficient, the slide must be moved over by hand with as uniform a motion as possible.

Outline of the photographic process to be followed.

Cleaning the plates.—All the glass plates, 7″ by 7″, are to be roughened on the edges with a sandstone and washed free from the grit. They are then to be immersed in dilute nitric acid, and left to soak for a short time. After being washed under the stream of water from a tap and rubbed with a clean piece of cloth at the same time, they are to be set up in the frames provided for draining. As soon as nearly dry, they are to be thoroughly dried with a chamois-skin and placed in boxes.

Albumenizing.—The glass plates are next to be albumenized. If fresh eggs can be procured, they may be used; otherwise the dried albumen must be taken. In the first case, the white of one egg is to be beaten up thoroughly and mixed with 16 ounces of pure water and filtered; in the second case, one ounce of the dried albumen is to be dissolved in 60 ounces of pure water, and, after the addition of 5 drops of nitric acid, is to be filtered.

The dry glass plates are to be flowed with this solution, taking care that none runs on the back, and set in the draining-frames to dry. The edge of a glass plate may be used to assist in procuring an even coating. The photographic house previous to this operation is to be sprinkled, swept, and dampened again. As soon as the plates are dry, they are to be put into the negative-boxes again. These boxes should be kept clean and free from dust and dampness.

The albumenizing is to be performed, if practicable, the day before the transit, and 200 plates must be prepared. The boxes containing the plates must be labeled 1, 2, 3, 4, 5, and set in regular order on a shelf near the nitrate-bath shelf. The chief photographer must, the day before the transit, number the plates with a pencil diamond on the back or non-albumenized side, beginning with number 1 on the left-hand side of box number 1, which should be at the left-hand end of the shelf as the operator faces the shelf. The object in view is to have the exposures made on a series of plates with consecutive numbers, so that a record may be kept in the book provided for the purpose, and, accordingly, the second assistant, who is to coat the plates with collodion, must be directed to take them out in regular succession.

Collodion.—The collodion to be used by the various parties must all be compounded on the same formula, in order to assist in securing uniformity of results, and to allow of a uniform method of reading the negatives. The formula to be used is:

Pyroxyline	80 grains.
Iodide of cadmium	96 grains.
Bromide of cadmium	8 grains.
Alcohol	8 ounces.
Ether	8 ounces.

In order to make the collodion fit for use at an early date, a few drops of an alcoholic solution of iodine must be added so as to communicate a reddish-yellow tint.

The chief photographer is to make only such changes in the above formula as are absolutely necessary to adapt the collodion to the temperature at his station.

The process of flowing and its details are left to the discretion of the chief; it being understood that the main object in view is to secure a film without thick and thin parts, and one which will give the sun of as uniform density as the nature of his light will permit. A well-marked outline must be obtained, and the central parts will necessarily be over-exposed so as to show but little detail.

Collodion in sufficient quantity to coat 200 plates must be prepared and tested several days before the day of the transit; indeed, this must be one of the first duties attended to on arriving at the stations. The collodion must not only be allowed to settle thoroughly, but must also be passed through the filtering-bottles provided, and then put away in stock-bottles. On the day of the transit both the filtering-bottles must be filled and kept in that condition. All the plates must be coated from them.

Nitrate of silver bath.—The nitrate baths are to be composed of 40 grains of nitrate of silver to the ounce of water, and are to be acidified in the proportion of 1 drop of pure nitric acid to 4 ounces of bath; three baths will be in use at a time. It will be desirable to use the purest water attainable; and if rain-water which has fallen on a clean roof at the end of a storm cannot be procured, a sufficient quantity must be distilled in the apparatus provided for the purpose. In either case it will be proper to add to the water a small quantity of nitrate of silver and a few drops of ammonia, and set the mixture in the sunshine for several hours. A supply of water sufficient to make at least six baths must be ready for December 8th. A few days previous to the transit six baths must be made up, and tried with *plates which have not been albumenized.* It must be recollected that albumen has a tendency to injure the nitrate bath, and cause markings on the plates, and hence fresh but still well-tried baths must be ready for the transit-day. Such baths as have been used with albumenized plates may be utilized by neutralizing them with a small quantity of carbonate of soda, and setting them in the sunshine. They may subsequently be filtered and acidified. The baths are not to be iodized; they must be tested with litmus paper before use, and must present a well-marked acid reaction.

Developer.—The pictures are to be developed with a solution made according to the following formula:

Sulphate of iron and ammonia	1 ounce.
Glacial acetic acid	2 drachms.
Alcohol	1½ ounces.
Water	16 ounces.

The exposure given by the sliding cut-off shutter must be sufficient to enable the above developer to bring out the picture in 30 seconds; and if the pictures are too feeble, the slit must be opened instead of increasing the time of development. The chief must modify the above developer to suit the temperature of his station, and must aim to get a sharp outline to the sun and not a picture full of shading and details. He must take care that the image of Venus is not fogged to any great extent.

Fixing.—The fixing is to be done with cyanide of potassium solution in the proportion of one ounce and a half to a quart of water. The plates made about the times of the contacts may be fixed with hyposulphite of soda in an India-rubber dish, so that the photographers may give all their attention to obtaining as large a number of photographs as possible at those times.

It is expected that during the transit at least 150 pictures will be taken; but the photographers are directed to finish each picture and fix it before putting it on a draining-stand. The only exception to be allowed is in the case of the contact pictures.

Varnishing.—After the transit is over, and as soon as the plates are dry, they are to be varnished in the customary manner.

Division of labor.—The duties of the photographers are as follows: One of the assistants is to coat the plates, immerse them in the nitrate bath, and take them out when so directed by the chief. He is to be careful to preserve the order of the numbers. Another photographer is to develop the plates and fix them; the first operation, including the washing, should not occupy more than one minute, and the second, a somewhat shorter time. A third is to take the plates from the assistant who coats them, place them in the exposure-frame, clamp them, make the electric signal, spring the exposure-shutter, note the time by a chronometer, take the number of the plate and the reading of the level and temperature, enter these and other particulars in the proper book, and hand the plates to the developer. The chief photographer must keep watch over his subordinates and see that their duties are properly performed. He is to obey such orders about times of exposure as the chief of the party may give.

During the two or three hours of intermission between the optical observations already directed, either the chief of party or first assistant should remain in the dark room to oversee the operations, and should then, so far as possible, relieve the photographers of the duty of making the exposures and keeping the record, so that two of them may attend to the development and fixing of the plates.

The chief must also make arrangements to have a plentiful supply of water for washing on hand on the day of the transit.

Special directions for taking reversed photographs of vertical lines of plate-holder.

1. Cover the photographic objective with a cap having a slit $\frac{1}{2}''$ wide through its center from top to bottom. See that this slit is truly vertical.

2. Cover one-half the plate with a screen fastened to it, and therefore turning with it, having one edge straight and vertical. This screen may be of yellow or black paper, entirely opaque to the photographic rays. The screen must be so arranged that when the plate-holder is reversed it shall cut off the rays of the sun which passed in the other position, and pass those which were before cut off.

3. See that when the plate-holder is reversed, the bubble of the level does not go to either end of the tube. If it does, the screw which adjusts the level of the cast-iron base on the pier must be touched until the bubble is in play in both the direct and reverse positions of the plate-holder. To do this it may be found necessary to adjust the level on the plate-holder; but this must only be done when absolutely necessary, and the fact of its being done must be entered in the journal.

4. Put a non-sensitized plate into the portable plate-holder, and put the latter into place by its guiding-pins.

5. See that the non-sensitized plate is parallel to the ruled plate, both in the vertical and horizontal direction. If not parallel, make it so by slightly turning the main plate-holder on its vertical axis, and adjusting the screw of the arm of the portable plate-holder. When parallel, the reflections of a candle from the non-sensitized plate and from the ruled plate will all coincide when seen through the flame of the candle itself from the back part of the photographic room.

6. Adjust the heliostat, and set it going, so that one-half the image of the sun shall be cut off by the screen on the plate-holder when exposure is made.

7. Replace the non-sensitized plate in the portable holder by a sensitized and albumenized one, and put the holder gently back into the position described in 4. Read the level, and make exposure. Owing to the covering of the objective, it will probably be necessary to move the slide by hand to get exposure enough.

8. The operator will then gently pick up the portable holder while an assistant reverses the main plate-holder on its axis, being careful to turn it exactly 180°. To indicate when to stop, suitable marks must be made.

9. The operator carefully returns the portable holder to the position described in 4 and 7, avoiding any jar which may change the position of the sensitive plate in the holder. The level is read, and exposure is again made, but not till the plumb-line has had ample time to come to rest.

When developed, the vertical lines should come out with all attainable sharpness and distinctness.

Always make the first of the pair of exposures in the direct position of the main plate-holder.

When satisfactory photographs are obtained in the manner described, put the screen on the other half of the plate-holder and repeat the process.

These reversed photographs must be taken on every sunny day during the month preceding the transit and the week following it. The set taken on each day must be accompanied by two photographs of the sun, showing the ruled lines, taken in the ordinary way without the screen, the arm of the plumb-line being reversed between the exposures. The level and the thermometer must be read in all photographs of the sun which are to be preserved.

Directions for measuring the distance between the objective and the photographic plate.

The long rod, being in place as already described, must lie quite straight, in a line passing directly over the centers of the objective and of the plate-holder. The observer must sight along the rod to see that it is straight, and if it is not the supports must be changed to make it so. Then hang one of the fine brass-wire plumb-lines over each end of the rod, the bob hanging in a vessel of water. Take care that the outer bob is completely under water, so as to be protected from the wind. When the plumb-lines are at rest, press the arms of the jaw-micrometer against the edges of the object-glass, and by the two rack-motions bring the end of the central arm gently against the face of the objective, and the jaws into such position that the plumb-line shall be seen through and between the pin-holes. The plumb-line can be best seen by looking through the holes with an eye-glass. In doing this, take great care to hold the micrometer horizontal. When all the adjustments are correct, read and record the vernier. When the measure is completed at the objective, pass to the plate-holder and take similar measures from the outside of the ruled plate. Each measure should be repeated several times by different observers, and each separate result should be recorded, with the initial of the observer, the temperature of the rod, and any other particulars necessary to a judgment of the observation.

Should the rod be too long, file a vertical notch on each side near one end, loop the plumb-line, and let it hang in these notches.

The distance between the surface of the ruled plate from which the measures are made and the collodion film when a picture is taken must also be repeatedly measured as accurately as the party is able to do it.

Memoranda of times and angles of contact.

The following are the supposed approximate positions of the stations. Some of the numbers may be incorrect, and therefore need a corresponding alteration:

Station.	Latitude.	Longitude west of Washington.	
		In arc.	In time.
	° ′	° ′	*h.* *m.*
Wladiwostok	43 7 N.	150 59	10 4.0
Nagasaki	32 45 N.	153 6	10 12.4
Peking	39 55 N.	166 28	11 5.9
Crozet's Island	46 27 S.	231 7	15 24.5
Kerguelen Land	49 38 S.	212 47	14 11.1
Hobart Town	42 53 S.	135 36	9 2.4
Bluff Harbor	46 37 S.	114 35	7 38.3
Chatham Island	43 48 S.	99 52	6 39.5

The Washington mean times of the several contacts are as follows:

Station.	First contact.		Second contact.		Third contact.		Fourth contact.	
	Time.	Angle Q_1.	Time.	Q_2.	Time.	Q_3.	Time.	Q_4.
	h. *m.*	°	*h.* *m.*	°	*h.* *m.*	°	*h.* *m.*	°
Wladiwostok	8 35.7	51.3	9 3.3	45.7	12 56.1	−16.6	13 23.8	−22.2
Nagasaki	8 36.7	51.1	9 4.3	45.4	12 55.0	−16.4	13 22.7	−22.0
Peking	8 37.6	51.1	9 5.3	45.4	12 56.8	−16.6	13 24.4	−22.2
Crozet's Island	8 50.0	47.3	9 21.9	40.6	12 43.8	−12.0	13 14.9	−18.7
Kerguelen Land	8 49.2	47.5	9 20.8	40.8	12 43.0	−12.2	13 14.2	−18.8
Hobart Town	8 42.5	48.8	9 12.5	42.2	12 40.8	−12.9	13 10.9	−19.2
Bluff Harbor	8 40.7	48.6	9 11.1	42.2	12 38.7	−12.5	13 9.4	−18.8
Chatham Island	8 39.2	48.8	9 9.3	42.4	12 38.3	−12.4	13 8.9	−18.8

The angles Q, when positive, as in the first two contacts, are counted from the north limb of the sun round toward the east; when negative, toward the west.

The times may be assumed as probably correct within half a minute, and certainly within a minute and a half. To this uncertainty must be added that of the longitude, or of error of the chronometer on Washington time, to find the uncertainty of the computed chronometer-time of beginning.

The following are the positions at which first contact occurs on the photographic plate. The observer standing in the dark room, facing the object-glass, as usual in taking the picture, and regarding the image of the sun on the photographic plate, will, at the northern stations, see the contact occur between the left-hand side and the bottom of the sun's image, and nearer the left-hand side. The exact angles from the bottom of the image toward the west are—

At Wladiwostok	63°
At Nagasaki	66°
At Peking	73°

At the southern stations contact will occur between the top and right-hand sides of the image, the following being the angles from the top of the image toward the west:

Crozet's Island	20°
Kerguelen Land	31°
Hobart Town	48°
Bluff Harbor	52°
Chatham Island	57°

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